Lidar Sensor –
Future Data Collection Process

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UF Background

- autonomous vehicle systems
  - model the environment (lidar & vision)
  - determine appropriate vehicle behavior

Overall Project Goal

- Can the Roadway Characteristics Inventory (RCI) process be made more efficient and cost effective by collecting and interpreting lidar point cloud data?

- 18 month project, $150K

Task List

Task 1   Perform a literature review of other state departments of transportation use of Lidar for data collection.

Task 2   Compare and contrast existing LiDAR units/systems and decide which unit/system will be the best for FDOT.

Task 3   Speak with District data collectors and data collection managers to set the benchmark for time, costs, safety, consistency of data collection, and return on investment as it exists today.

Task 4   Use a LiDAR unit to collect RCI data then compare its time, cost, safety, consistency of data collection, and return on investment to each Distr

Task 5   Determine the feasibility of FDOT to perform in-house LiDAR collection and RCI feature extraction.

Task 6   Prepare draft and final report.

Task 7   Final report.

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Task 1 – Literature Review

- identified 31 papers and reports that are related to sensor based data collection
  - several lidar cases had data taken from the air
  - some papers concluded that lidar data provided a higher than necessary level of detail and that other less costly alternatives existed (vision)
  - several papers described combining lidar and vision
  - FDOT District 4 paper published in 2013 was very relevant
    - vision and lidar data collected in the field and analyzed manually in the office
    - collection process was simplified and collection times were improved
    - analysis time took too long and made the effort not economical

Task 1 – Literature Review, Conclusions

- Lidar sensors generate an abundance of data. A typical sensor can collect approximately 50 MB of data in 1 minute. Structuring this data so that it can be processed and managed efficiently is a challenging problem.

- The accuracy of range data varies between sensor models. A point cloud generated by a sensorwhose range values are within ± 1 cm will be much easier to analyze than a point cloud generated by a sensor with a range accuracy of ± 3 cm.

- The position and orientation accuracy for a mobile sensor is very important. GPS and inertial sensors must accurately report the correct sensor position so that data points can be accurately merged.

- Characterization of objects in the point cloud is a difficult problem. Most researchers have used random seed points to begin point grouping.

Task 1 – Literature Review, Conclusions

- Cost, both personnel and hardware, is not discussed in most of the references with the exception of the District 4 report.

- Upon reviewing the literature, a system combining vision and lidar may be best able to classify highway features. A combination of color information from the vision sensor and range and reflectance data from the lidar may result in a more robust feature classification algorithm.

Task 3 – District Meetings

- Visits

  - District 6 – Ft. Lauderdale, 13 July

  - District 4 – Miami, 14 July

  - District 3 – Chipley, 18 July

- Discussion

  - measurement accuracy

  - feature extraction is key

  - important features
    - sidewalks, medians, intersections, shoulders, curbing, thru lanes, turn lanes

  - test sections of highway identified

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Administrative Features (22)

111	State Road System
112	Federal System
113	AASHTO
114	Local System
118	HPMS
119	HPMS Universe
120	Typeroad
121	Functional Classification
122	Facility Classification
124	Urban Classification
125	Adjacent Land Classification
137	Maintenance Area Boundary
138	Roadway Realignment
139	New Alignment
140	Section Status Exception
141	Stationing Exceptions
142	Managed Lanes
143	Associated Station Exception
144	Fla. Intrastate Hwy System
145	Level of Service Input Data
146	Access Management
147	Strategic Intermodal System

Maintenance Features (17)

411	Roadside Mowing
412	Weed Control
413	Landscape Area
421	Roadside Ditch Cleaning
422	Median Ditch Cleaning
431	Parks and Rest Areas
443	Delineators
451	Striping
452	Symbols and Messages
453	Cross Walks
454	Stop Bars
455	Raised Pavement Markers
456	Retroreflectivity Measurement
457	Retroreflectivity Parameters
460	Attenuators
480	Highway Signs
481	Highway Maint. Classification

Operational Features (13)

311	Speed Limits
312	Turning Restrictions
313	Parking
320	Mile Marker Signs
322	Signals
323	School Zones
326	Traffic Monitoring Sites
330	Traffic Flow Break Station
331	Traffic Flow Breaks
341	Lighting System
351	Motorist Aid System
360	Toll Plazas
361	Service Plazas

Physical Features (26)

212	Thru Lanes
213	Auxiliary Lanes
214	Outside Shoulders
215	Median
216	Bike Lanes/Ped Sidewalk
217	Sidewalks
219	Inside Shoulders
220	Non Curve Intersection Point
221	Horizontal Curve
230	Surface Description
232	Surface Layers
233	Base
241	Crossdrains
242	Storm Sewers
243	Off Roadway Areas
245	Roadside Ditches
248	Outfall Ditches
251	Intersection
252	Interchanges
253	Railroads
256	Turnouts
257	Crossovers
258	Structures
271	Guardrail
272	Fencing
275	Misc. Concrete Structures

Rail Line (1)

901	Rail Line Facility

Scope:

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Task 2 – Survey of Lidar Units

- Is there a suitable lidar unit in the price range of $8-9K that can acquire sufficient data for RCI?

Equipment

inclination and magnetic sensors

Velodyne 'puck' lidar

VLP-16

Sensor:

- Time of flight distance measurement with calibrated reflectivities
- 16 channels
- Measurement range up to 100 meters
- Accuracy: +/- 3 cm (typical)
- Dual returns
- Field of view (vertical): 30° (+15° to -15°)
- Angular resolution (vertical): 2°
- Field of view (horizontal/azimuth): 360°
- Angular resolution (horizontal/azimuth): 0.1° - 0.4°
- Rotation rate: 5 - 20 Hz
- Integrated web server for easy monitoring and configuration

Schedule

- 14 May: pre-survey of site 1

- 17 May: post-survey of site 1 ;
       pre-survey of site 2

- 25 May: post-survey of site 2

Post-survey of site 1

- Scans performed from three vantage
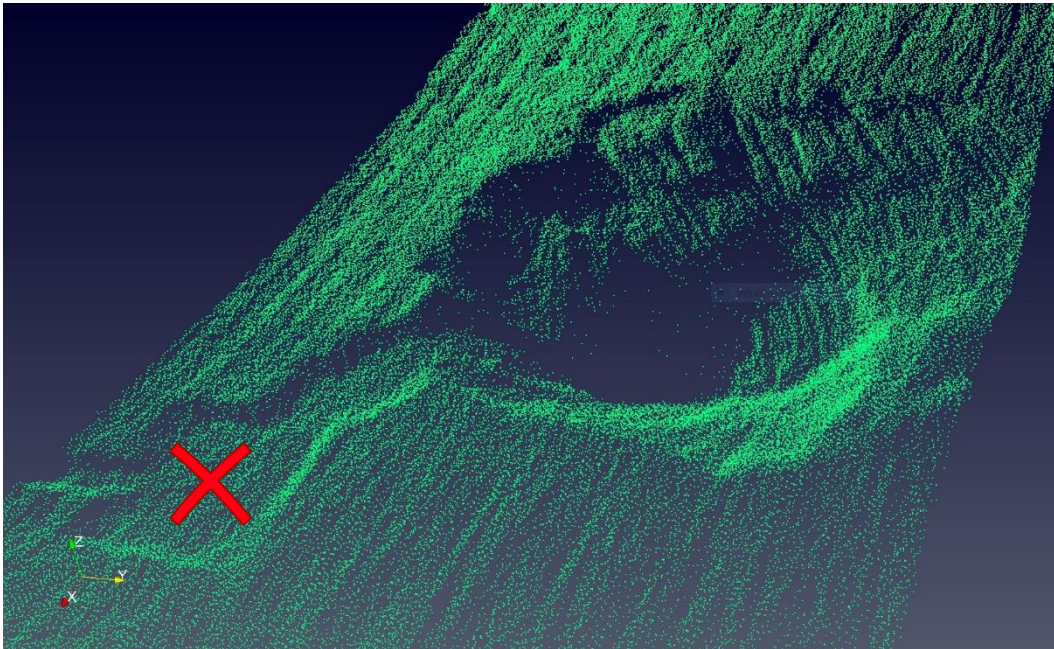
Site 1: Three data sets merged (cloud compare)
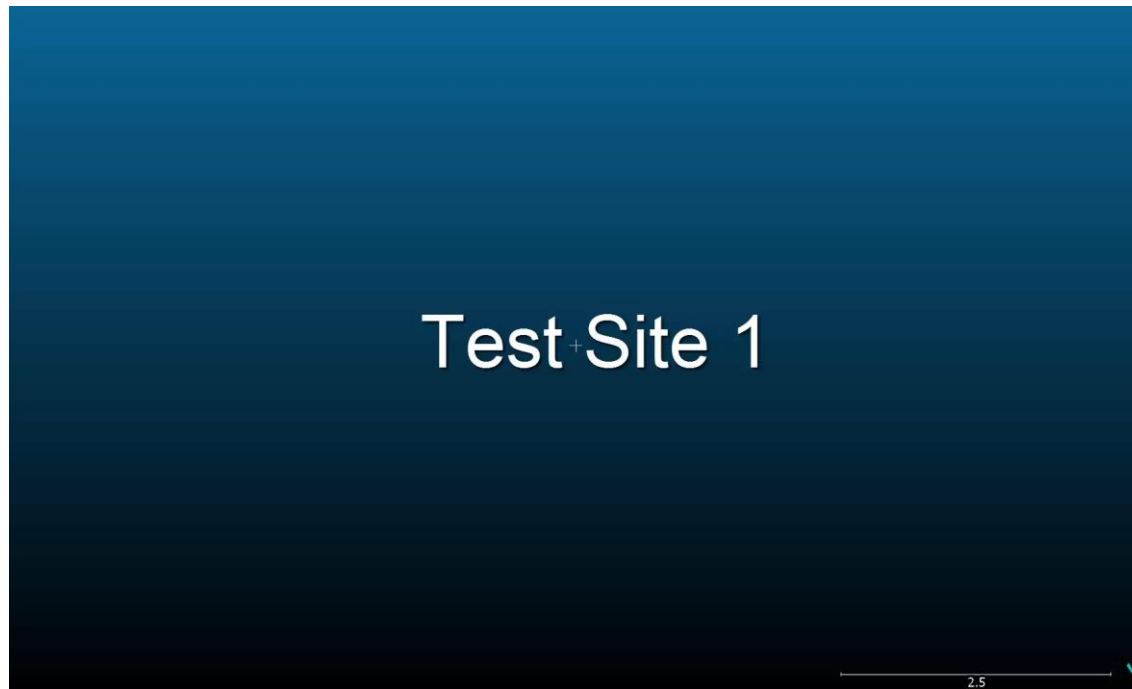
Test Site 1

Site 1: Merged point cloud imported to SolidWorks
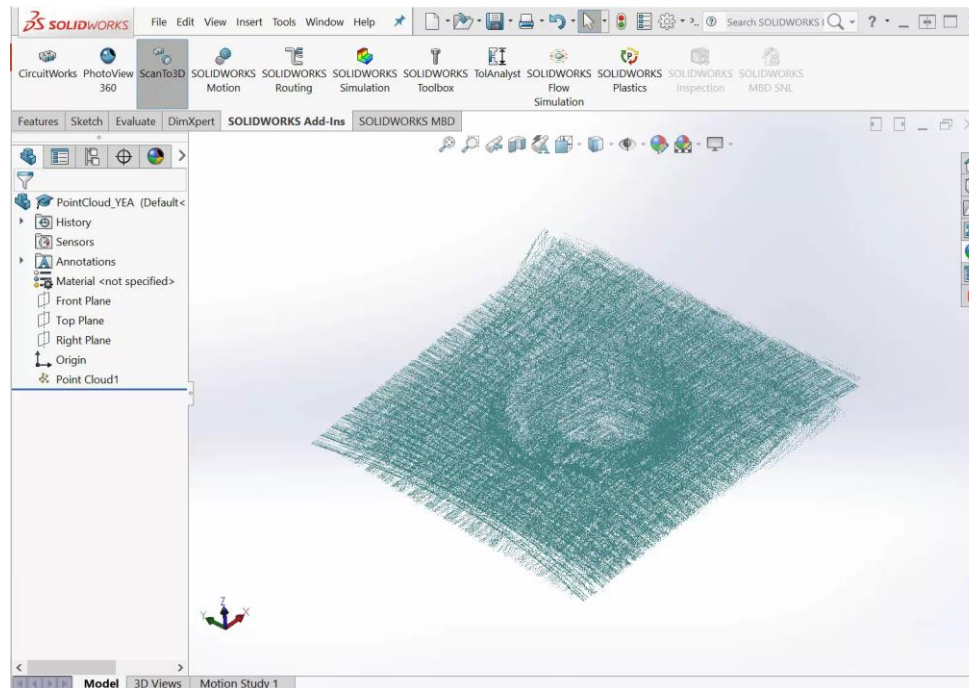
Attempt to mesh (geomagic trial software)

Current Triangles: 545,863
Selected Triangles: 0
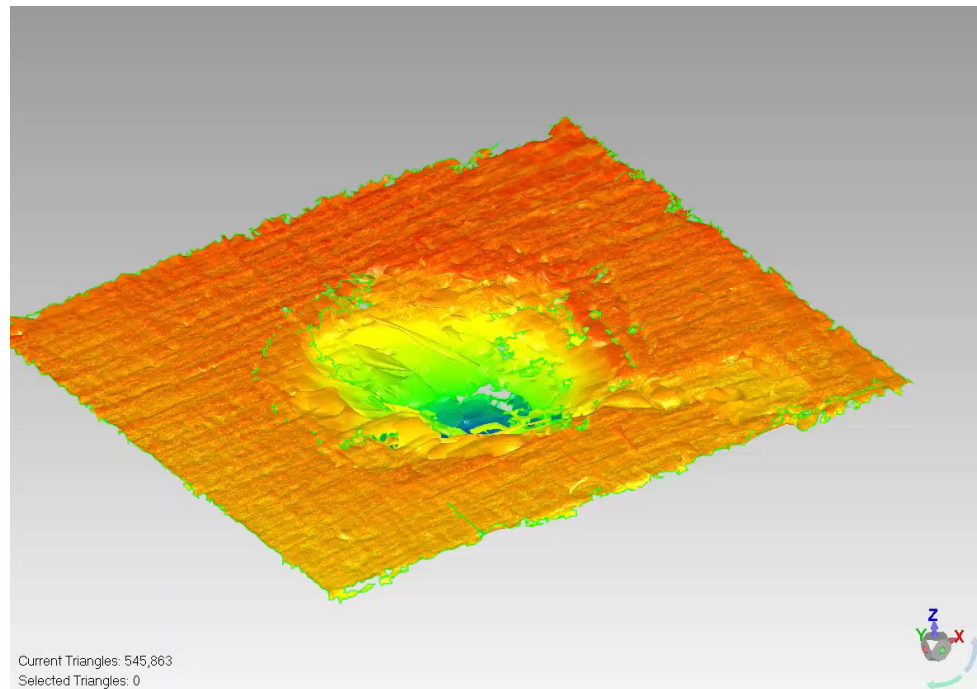
problem with filling all holes to obtain a 'water tight' surface

Task 2 – Survey of Lidar Units

- cost constraint is $8.5K

- will run preliminary tests on two units before making recommendation to purchase

Velodyne VLP-16

Sick LMS-100

Task 4 – Data Collection & Interpretation

- acquire lidar unit

- design data acquisition apparatus

    - require accurate position and orientation data

- data storage and interpretation

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Florida Permanent Reference Network (FPRN)
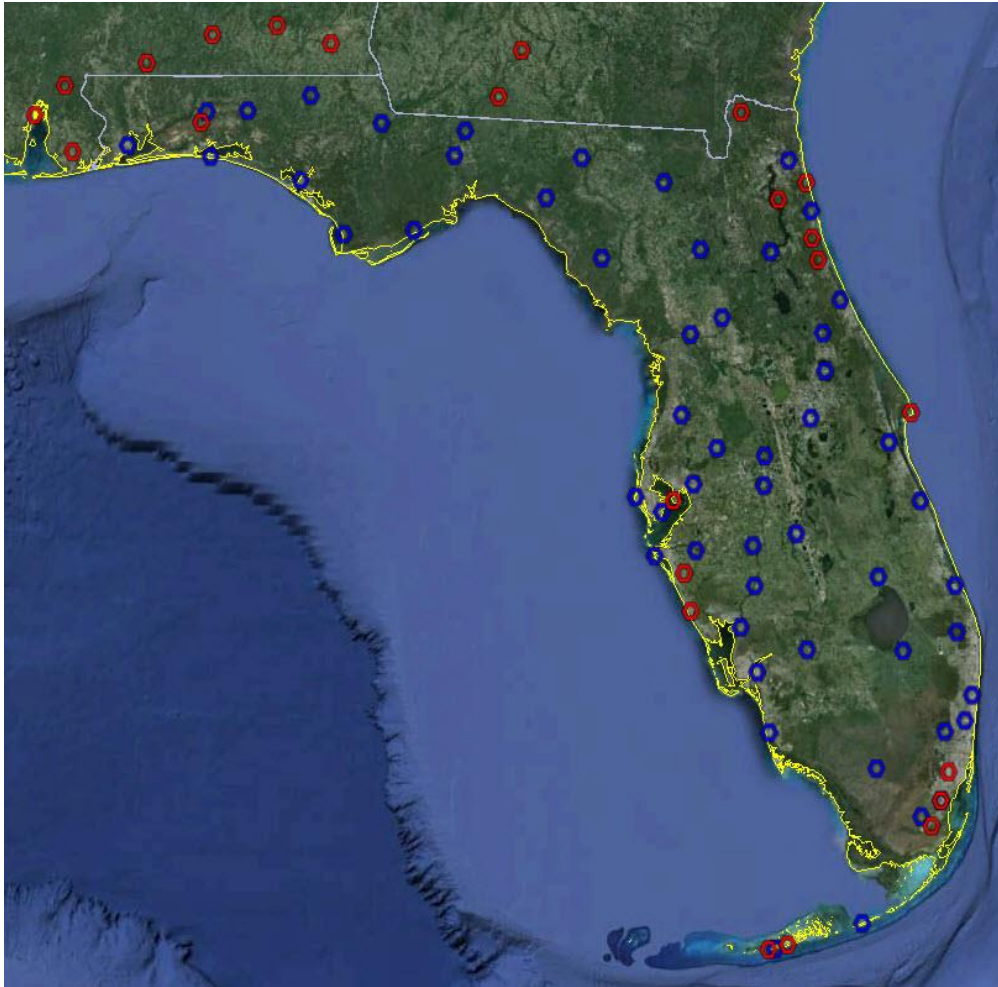
RTK data corrections augment GPS to give cm level accuracy.

Low cost GPS (~$200) combined with this system will replace $8K GPS with $1.5K annual subscription.
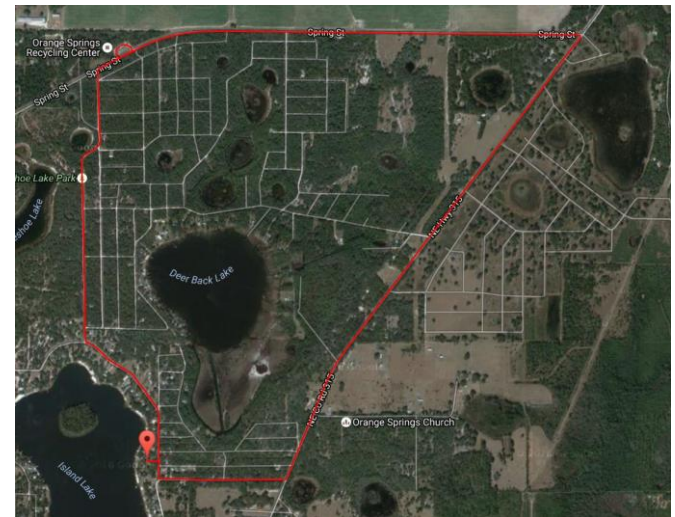
Voxel Based Data Representation
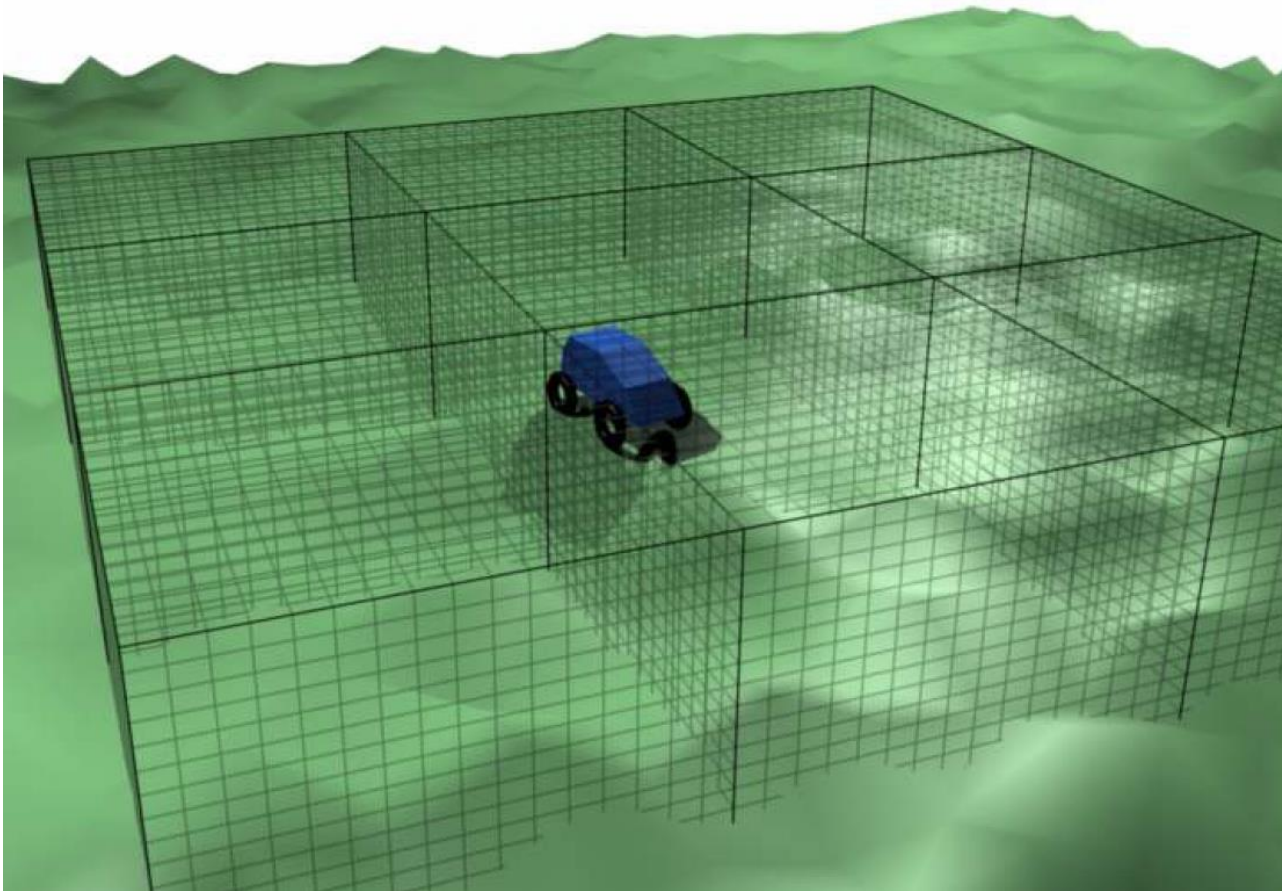
Voxel Occupancy

- A 3-D version of Bresenham's line function is used to determine all the cells through which a line segment passes.
- Occupancy of free space voxels are decremented.
- Occupancy of object voxels are incremented.
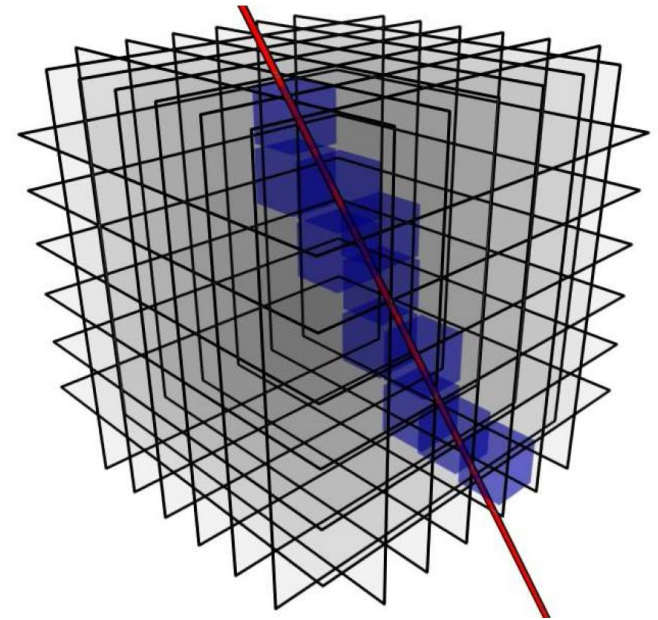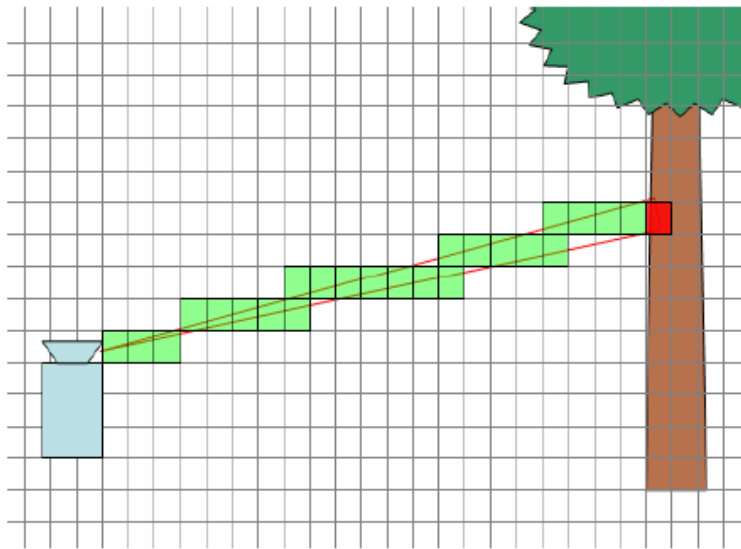
Implementation – Identify Ground Surface

- Identifying the voxels that make up the ground surface is critical.
- It can be assumed that there will be no occupied voxels below a ground surface voxel.
- Also, since no beams can penetrate below the ground surface, there should be no voxels with a free space value (known zero occupancy) below a ground surface voxel.
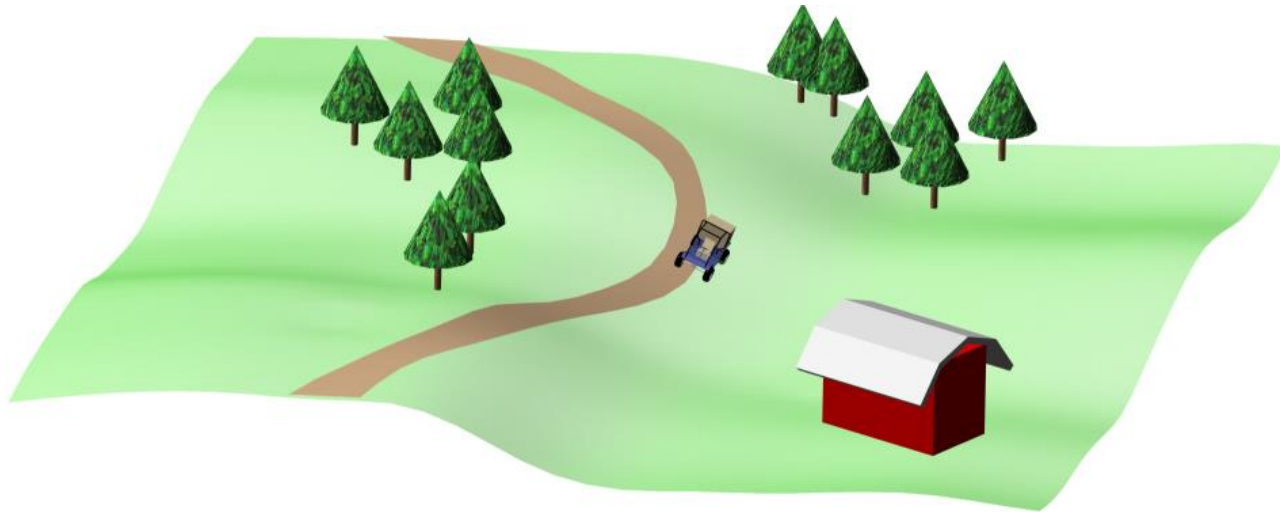
Identify Ground Surface

- Candidate ground surface voxels are evaluated one at a time.

- A pyramidal region of a certain depth and slope is defined below the candidate voxel.

- While searching through the pyramid, if

  - an occupied voxel or known free space voxel is found within it, the voxel fails the ground surface test

  - otherwise, the candidate voxel is marked as being part of the ground surface.
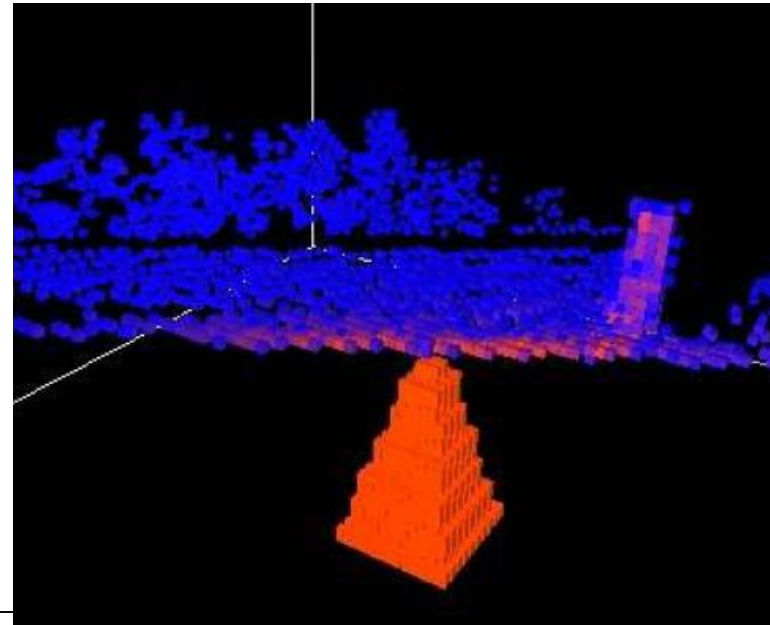
Implementation

- Identify Ground Surface
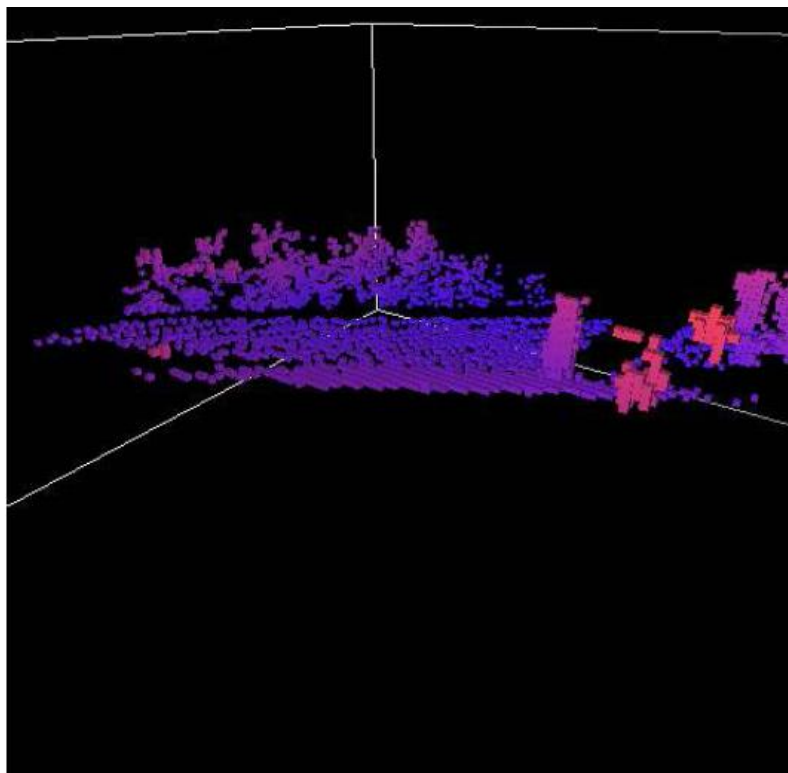
original voxel scene
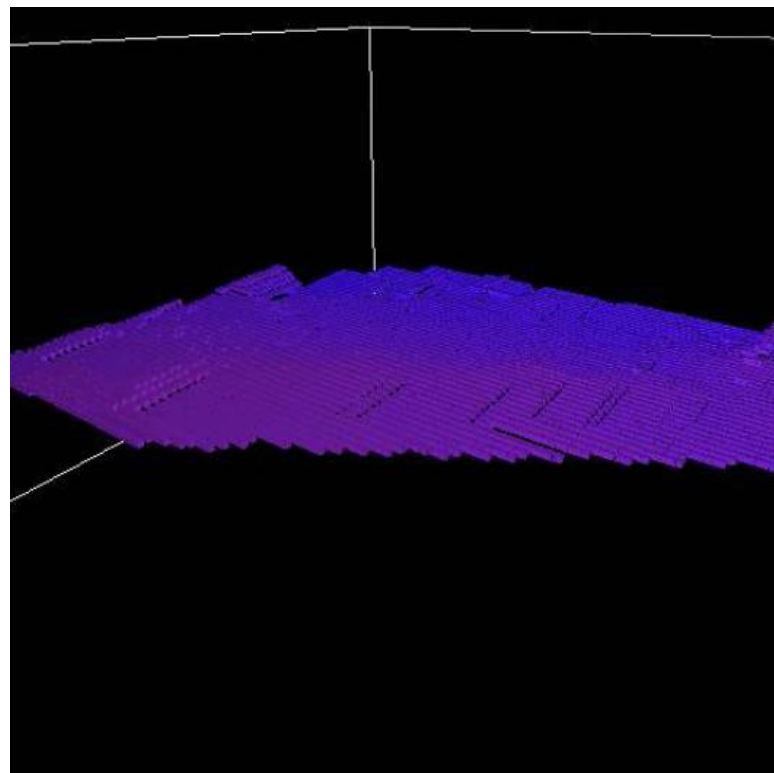
ground surface after blending

Implementation

- Estimate object heights ; Identify Tree Trunks
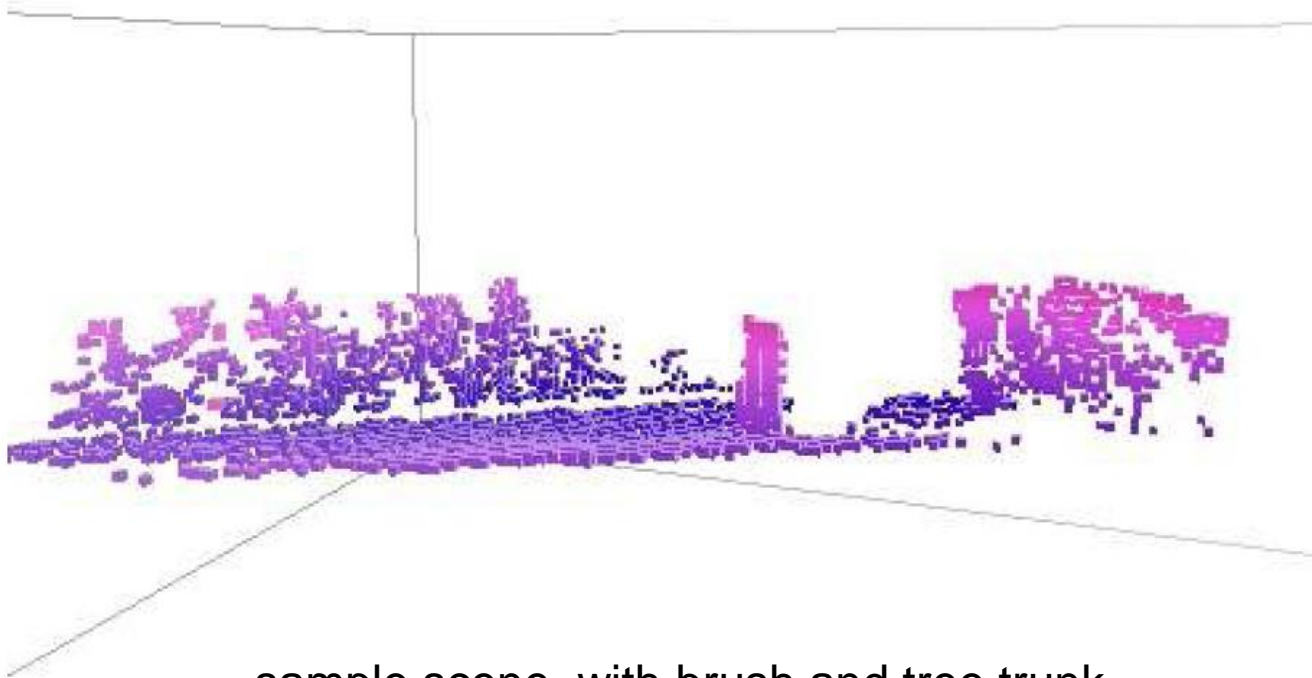
sample scene with brush and tree trunk

Implementation

- Estimate object heights ; Identify Tree Trunks
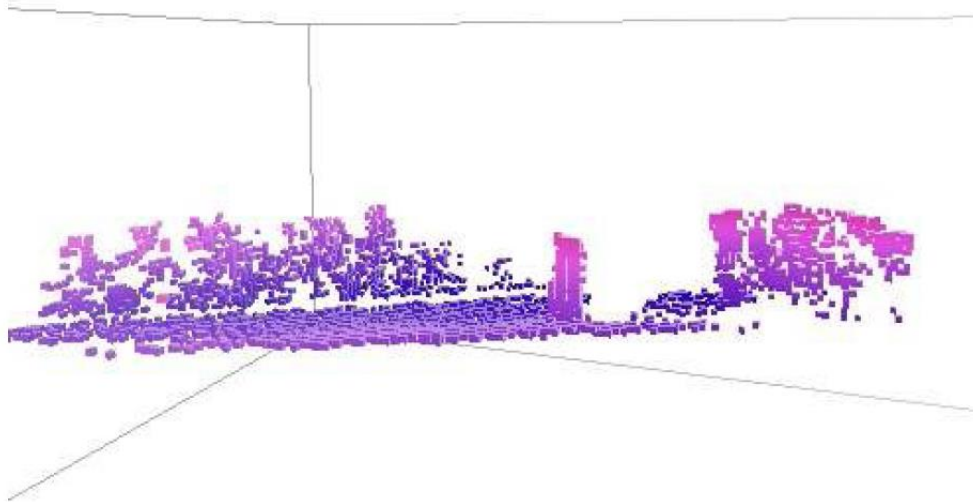
create above ground density plot
- 2D array
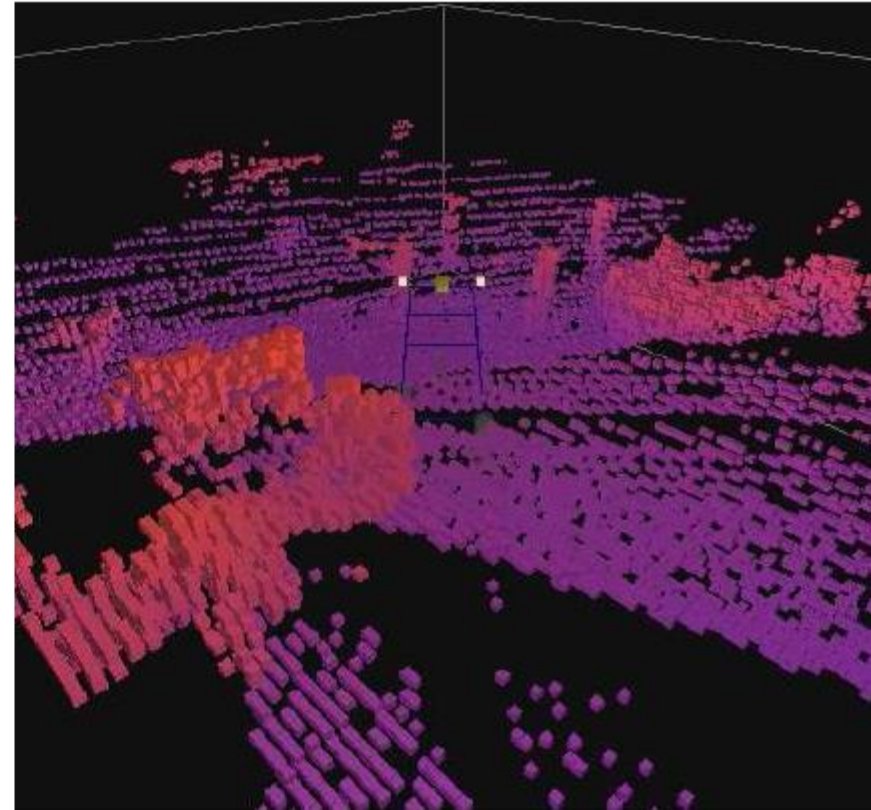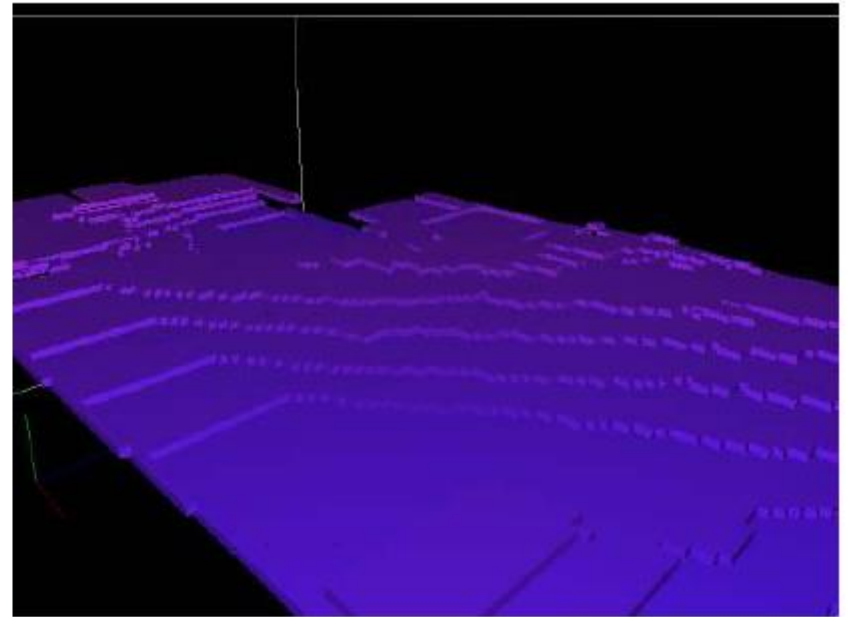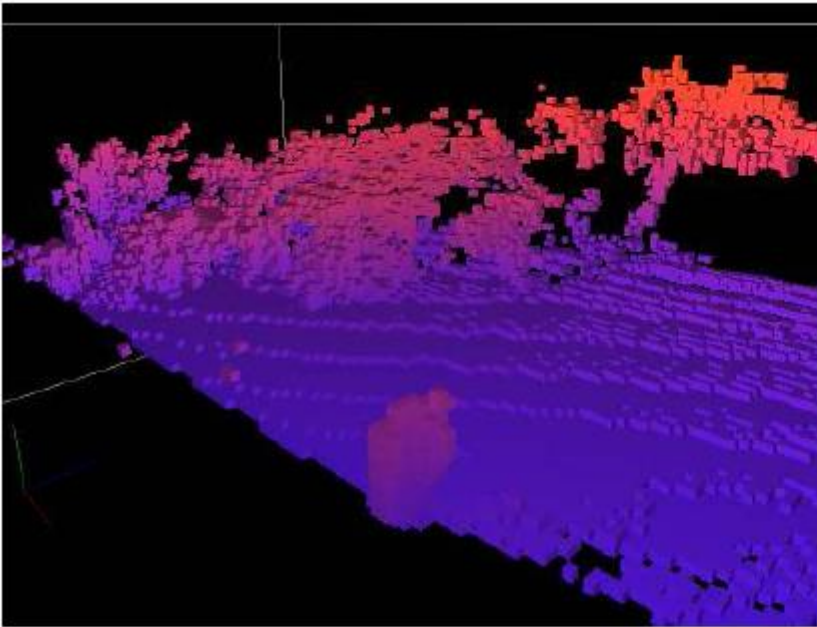- each array position stores the number of voxels occupied above ground

top down view with ground voxels removed
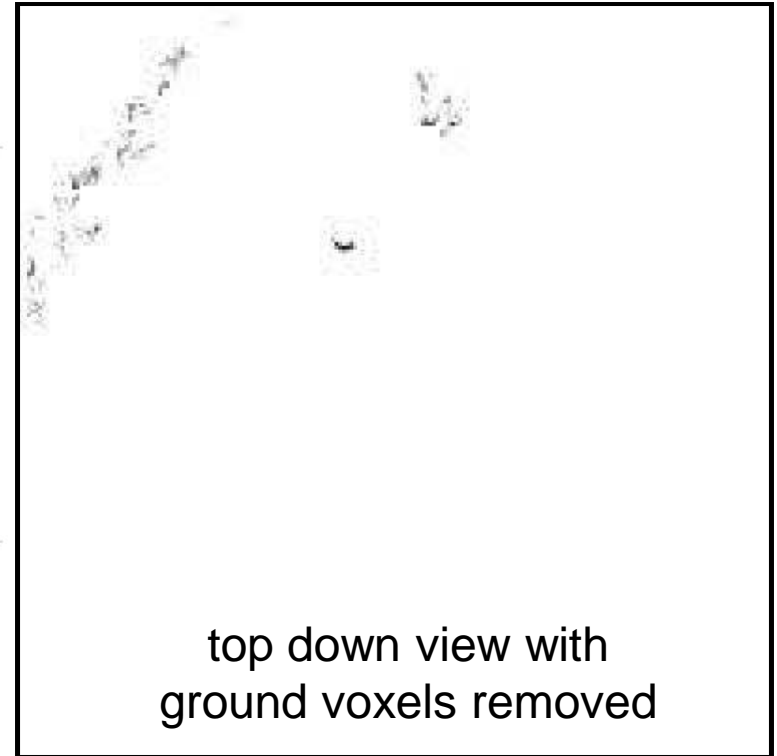
Results

- ## Sample Data Set – Dynamic Case

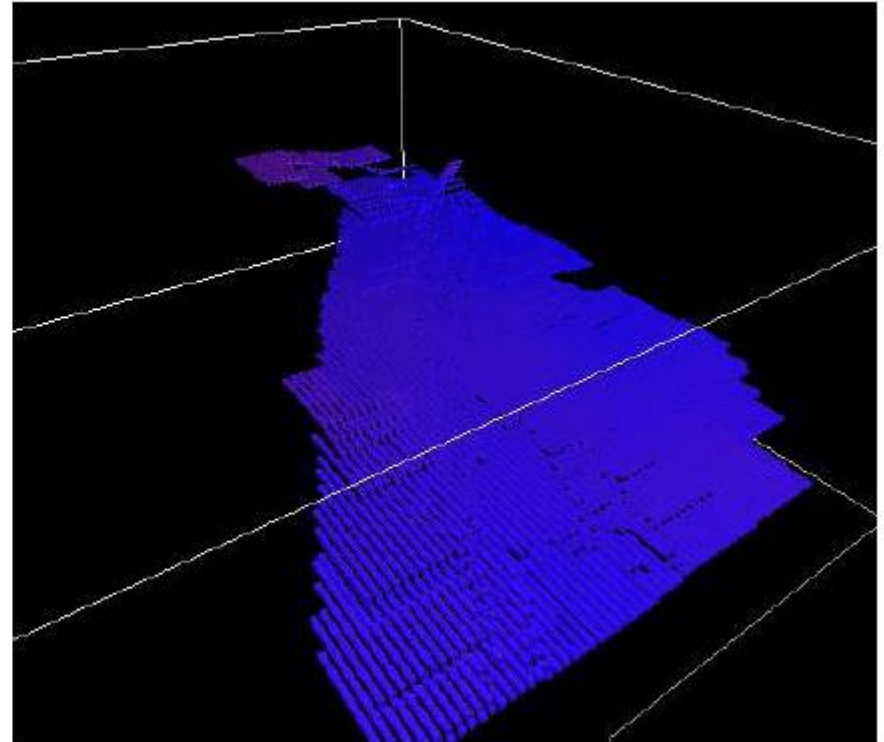image & snapshot of the voxel data taken at the same time
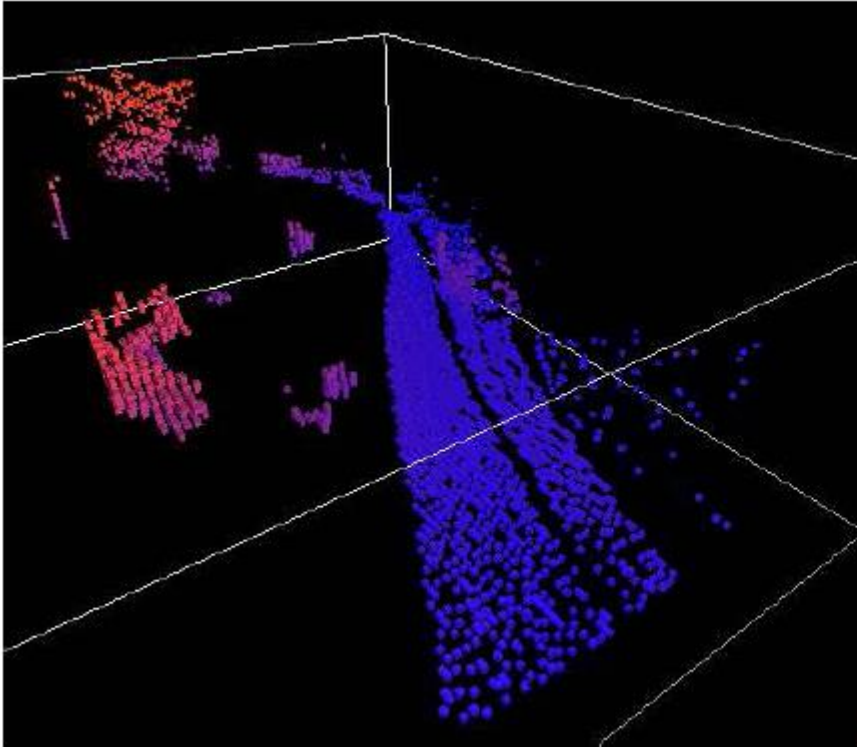
Results

- Sample Data Set – Dynamic Case

Results of ground surface identification among heavy brush.
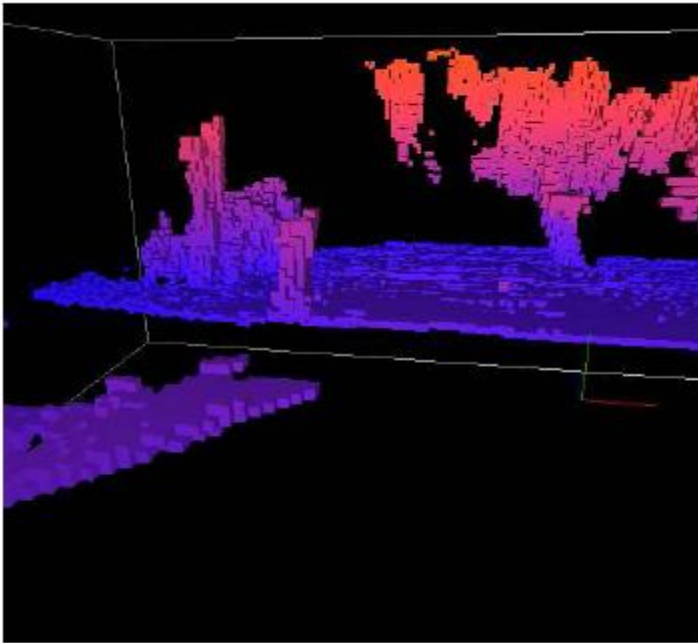
Results

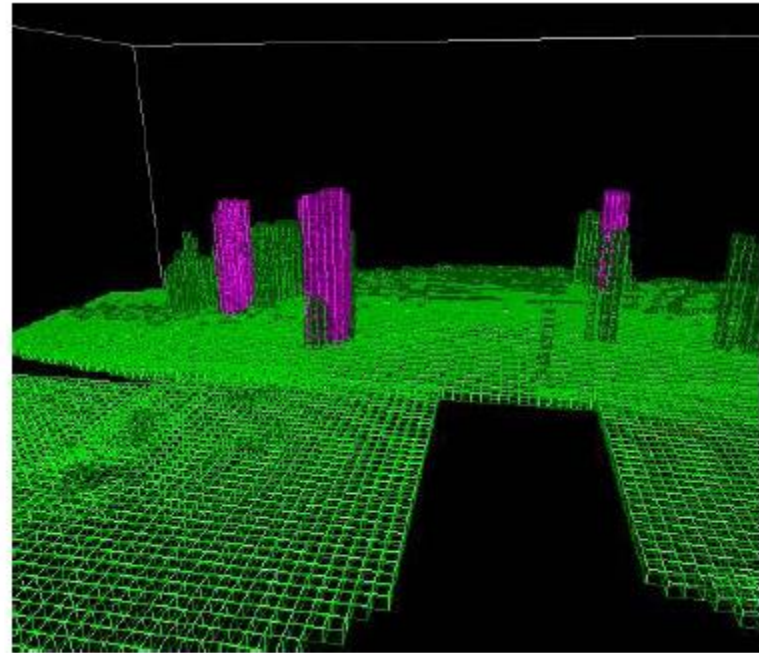- ## Sample Data Set – Dynamic Case

Results of ground surface identification with sparse data.

Results

- Sample Data Set – Dynamic Case

original data colored by height

Green voxels represent the ground surface, dark green the brush, and purple the tree trunks.

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Summary

- Task 1 – Literature Review, complete
- Task 3 – Site Visits
  - visits conducted
  - test highways identified
  - report to be written
- Task 2 – Survey Lidar Units
  - candidates identified
  - one unit tested in the field
  - need to test two models before deciding on sensor
- Task 4 – Data Collection & Identification
  - approach developed